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Effects of physical efforts on injury in elite soccer

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Running head: Physical performance and soccer injury

Abstract

In this study, the influence of physical efforts on occurrence of match injury in a professional soccer club was investigated. Computerised motion-analysis was used to measure the physical efforts of players during 10 injury situations. Total distance and those covered at different movement intensities were measured across the 5-minute period preceding injury. If the final run preceding injury involved a high-intensity action (HIA), the distance, duration and speed of the effort and the recovery time between this and the penultimate HIA were measured. To determine the influence of these physical efforts, the results were compared to a normative profile for players computed from data across 5 games for the same variables; habitual distances covered over a 5-minute period and characteristics of and recovery time between HIA. Compared to the normative profile, no differences were reported in physical characteristics during the period leading up to injury or for HIA although the latter were substantially higher in intensity (duration and distance). A lower than normal recovery time between HIA prior to injury was observed (35.6±16.8 s versus 98.8±17.5 s, p=0.003). Within the limitations of the small sample, these findings may aid in further understanding injury and physical performance in elite soccer.

Key terms: injuries, motion analysis, football incident analysis, fatigue

Introduction

Soccer (Association Football) is a complex contact sport with high physical, technical, tactical, and physiological demands at the elite level [10], and the risk of injury is considerable [26]. In order to suggest preventive strategies specific to soccer, it is necessary to have detailed information on the injury mechanisms involved. Previously, analysis of soccer incidents that combines game-specific and medical information has been employed to describe how injuries and high-risk situations of injury occur in match-play [1,2,3,5,23]. Examination of the playing situation, athlete-opponent interaction, and refereeing has highlighted the importance of tackling duels and heading duels as high risk situations. In addition, a critical incident technique was designed to identify behaviour with potential injury risk [32]; the findings emphasised tackling, receiving a tackle and charging an opponent as the circumstances with the highest injury potential.

A precise description of the inciting event is a key component in understanding the causes of injuries in sport [7]. In soccer, there is a need to investigate the effects of the physical efforts of players on the occurrence of injury [9]. The physical demands of match-play can now be easily and accurately investigated via information collected using computerised motion-analyses of player movements. Yet, to date, the effects of movement intensity when injuries are incurred has received scant attention. Furthermore, in the studies that have touched on this area [1,2,3,5], movement intensities were recorded subjectively and no comprehensive data were provided on specific running characteristics such as starting, average or maximal running speed or on the length or duration of actions. Similarly, no study has examined the possible effects of physical efforts prior to the injury situation. Related research by Rahnama et al. [32] reported an increase in critical incidents and injury risk in the first 15 min and in the last 15 min compared to other periods of the game. The presumption was that injury risk was associated to the periods in which exercise intensity was highest when players were fresh and lowest when players experience fatigue during the game, but there were no measurements of players' movements recorded. As players commonly experience transient fatigue in match-play notably after periods of intense exercise [8,28], motion analysis techniques could be used to determine whether greater than usual periods of intense exercise or inadequate recovery time between high-intensity efforts predispose a player to injury [9,10].

Therefore, the aim of this investigation in an elite soccer club was to examine the physical efforts of players in the period leading up to and for the final running action in occurrences of injury in professional match-play.

Methods

In the present study, injuries sustained during competitive matches (a total of 54 League matches from mid-season 2007-08 to end of season 2008-09) in players belonging to a 1st Division French League Club had been prospectively diagnosed and documented by the team's physician in a sports injury database (TeamSanté, Enora Technologies, Paris, France). Player consent and local ethics committee approval were obtained.

The methodologies and definitions of injury used in the present study closely follow those recommended by International Soccer Injury Consensus Groups [16,22]. A total of 47 injuries forcing a layoff of over 48 hours not including the day of injury [24,29] were available for analysis. Information including the type, location and cause of injury and the match period during which each injury occurred (matches were divided into six 15-minute periods, i.e., 0-15min, 15-30mins and 30-45mins for each respective half) was available. Also stored in the database was information on whether the player was forced to leave the field due to injury and the total number of days the player could not participate fully in training and competition. This latter number was used to calculate the severity of injury [16]. The severity of each injury was defined as slight, minor, moderate, or major depending on whether the player was absent from training or competition for two to three days, four to seven days, one to four weeks, or more than four weeks respectively [24,29]. Finally, descriptive information on the final action at the time the injury was sustained and whether contact had occurred between players was recorded.

The occurrence of injuries in soccer match-play cannot always be clearly identified on video recordings [27]. Often there is no stoppage in play and players do not go down on the pitch to receive treatment and are subsequently substituted at half-time or receive treatment after the match [1]. Therefore, only injuries that had forced the player to immediately leave and not return to the field of play were included for investigation. This process also helped avoid the inclusion of situations where players intentionally lay down either to rest, feign injury or delay playing time [17]. To reduce the effects of opposition behaviour, only injury incidents where no foul-play was observed (decision by referee to award a free-kick) were considered. These strict inclusion criteria limited the total number of injuries to 17 (36.2% of the total injury sample obtained over the two seasons).

After retrospective review of the medical records by the same club physician who had diagnosed the injuries, each injury incident was cross-referenced to determine whether the match had been recorded and analysed by the multiple-camera player tracking system (AMISCO Pro, Sport-Universal Process, Nice, France) used by the club to evaluate physical, technical and tactical performance in competition. A validation of this system has demonstrated high-levels of validity, accuracy and reliability in measuring player movements in elite soccer play [41]. If information from the system was available, the physical performance data were then used to measure the efforts of players over 5-minutes leading up to and during the injury situation. To obtain the time of injury, the club physician and the injured player reviewed the digital video recording of the injury incident and the time corresponding to the incident was obtained from the digital time code. Altogether, data were available for a total of 10 of the injuries (21.3% of the total injury sample).

To investigate the effects of physical performance prior to injury, the total distance and distance covered in four categories of movement intensity were measured over the 5-minute period preceding the time of injury: 0-11 km/h (walking, jogging or WJ); 11.1-14 km/h (low-intensity running or LI); 14.1-19 km/h (moderate-intensity running or MI); >19.1 km/h (high-intensity running or HI) [11]. To determine whether performance over this 5-minute period may have influenced injury, data across five completed matches were used in an attempt to establish a normative physical performance profile for each player [11,12]. For this profile, the total distance covered in each category of movement intensity was calculated for entire games. To calculate the distance covered over a 5-minute period, the total distance covered was divided by the match duration (in minutes) and then multiplied by 5. This figure was considered to be the player's habitual match-play activity level over a 5-minute period. The physical performance data used for the normative profile were based on information during the same season in which the injury occurred. The normative profile was subsequently compared to the physical efforts over the 5-minute period prior to injury.

The characteristics of the final running action in each injury situation were investigated. The starting and maximal running speed of actions and speed at time of injury were documented as were the duration, distance covered and average speed of the movement.

It has been suggested that players may be more at risk of incurring injury during HI activities [9]. If the player reached a speed >19.1 km/h for a minimum of 1 second duration at any time during the final running action, then the effort was considered to be a high-intensity run. Therefore, those injuries that had been identified as occurring during a HI exercise bout were investigated to determine whether the characteristics of these running actions differed from the player's habitual HI profile for this form of game activity. For this purpose, a normative profile was created for the speed, distance and duration of HI actions for five 90-minute games for each player and in which the player did not incur an injury. This result was compared to the same data obtained from each individual injury action.

Finally, to determine whether recovery time may have played a part in injury, the time between the penultimate HI effort and the HI action leading to injury was determined. Again, this result was compared to a normative profile for each player created from the calculation of the average recovery time between HI actions over five full games.

Statistical analyses of the dataset were performed using paired t-tests to test for differences in physical activity profiles prior to and during the injury situation and those obtained from the normative profiling of the same player's performances. The level of accepted statistical significance was set at $p<0.05$. To control the Type-I error rate observed in multiple measures of physical performance in competitive soccer, a pseudo-Bonferroni's adjustment is used through dividing the alpha level by the number of categories in which objective measures of physical performance are classified [12,35,36]. In this case, the three normative profiles were utilised to compare performance: physical efforts over a 5-minute period, characteristics of HI actions and recovery time between bouts of HI exercise. Thus, an operational alpha level of 0.017 ($p<0.05/3$) was used. Effect sizes for these differences were also determined. Effect size values (using Hedge's adjustment for small sample sizes) of 0.2, 0.5 and above 0.8 were considered to represent small, intermediate and large differences, respectively (13).

Results

Information on the characteristics of injuries and the final running action in each injury situation is reported in Table 1.

Out of the 10 injuries, 60% were diagnosed as sprains while strains (20%), bruising (10%) and a combined fracture/dislocation (10%) were also recorded. Injuries to the ankle region were more common (50%) while the upper leg (30%) knee (20%) were also affected. Altogether, 80% of injuries were considered to be of moderate severity while the remaining part (20%) was classed as major injuries. Finally, only two injuries (20%) were sustained in the second half and a greater proportion of injuries (60%) involved physical contact between players.

The starting speed in all but one action was observed to be at low exercise intensity. Altogether, 8 out of 10 of the final running efforts before the injury was incurred involved a HI run (>19.1km/h) and the average speed of movement of these final actions was within the moderate-intensity range (~17 km/h). In a third of the movements (33.3%), the speed at the time the injury was sustained corresponded to moderate intensity.

Insert Table 1 about here.

The total distance and the distance covered at different intensities of movement in the 5-minutes prior to injury compared to the habitual physical performance profile of players are presented in Table 2. The lack of significant differences reported for any of these measures of physical performance were accompanied by insignificant to intermediate effect size differences. However, players covered around a third more distance (35%) at high running intensities before sustaining an injury compared to typical performance over a 5-minute period.

Also presented in Table 2 is information on the average speed, length, duration and recovery time of the eight HI actions that led to injury compared to the habitual characteristics of HI efforts in the same players. While no significant differences were obtained, results showed that these final HI actions leading to injury were almost double the length and duration of usual actions. These differences in action length and duration were accompanied by intermediate effect sizes (>0.5). In contrast, the recovery time between the penultimate HI effort and the HI action leading to injury was shown to be significantly shorter compared to the habitual recovery time between HI bouts (p=0.003). This difference was accompanied by a large effect size (>0.8).

Insert Table 2 about here.

Discussion

The aim of this first study was to analyse the physical performance of elite soccer players in competition prior to and during actions leading to injury using motion analyses. Within the limitations of the small sample, the running actions in the injury cases indicated that at the time of injury, players were generally moving at moderate speeds after having started their final run at low speeds before attaining high intensities and then reducing speed. Analysis of the characteristics of high-intensity bouts in the injury situation showed that these actions were greater in both distance and duration, albeit non-significantly, compared to the player's usual efforts. While the players' overall efforts in the 5-minute period leading up to injury did not seem to play a direct part in the injury, a significantly lower than normal recovery time between high-intensity actions prior to sustaining injury was observed.

A large proportion of injuries sustained in professional soccer players are sustained during running actions [24] but little is known about the characteristics of these movements. In the present study, analysis of the running actions in the match injury situation showed these involved relatively high movement speeds (~17 km/h). Review of the injury situations showed that games skills, physical contact and injury avoidance behaviours were also superimposed on the locomotor activities leading to injury. The majority of the final running actions initially involved an acceleration phase from low to high running intensities, attaining speeds of over 23 km/h (for example to create space or close a player down), before the player decelerated to moderate speeds (generally when attempting to gain possession) at which the injury occurred. These acceleration and deceleration characteristics of running actions are highly common to the game of soccer. In the latter, impairments in the eccentric muscle contractions involved in such phases may be linked to an increased risk of joint and muscle injury [21]. Indeed, a recent review on soccer performance has identified a need for specific deceleration exercises in strength and conditioning training sessions [9] which could have some relevance for preventing some of the injuries identified in this and other reports [24,29,40] on soccer match-play.

In elite soccer match-play, high-intensity actions are rarely more than 20 metres in length and greater than 4 seconds in duration [14,18]. The present results from the normative analysis of player performance confirm this trend. While no significant differences were reported in distance or duration for the high-intensity run that led to injury, values for these measures were almost twice that of the normative profile. This finding suggests that players may be more at risk of injury when subjected to high-intensity bouts of exercise that are greater than usual in intensity. This observation could have important implications for the design of high-intensity running regimens. However, in the majority of the high-intensity actions that led to injury, players were in situations where they were challenging for possession. Further work combining injury and physical performance data is needed to examine whether the risk of injury is greater in situations where the player is tackling or being tackled which simply happen to be accompanied by high-intensity activities.

The physical efforts in the five minutes prior to the injury situation did not seem to play a role in causing injury. While players covered a slightly higher overall distance (+4%) than they would during a typical five-minute period of play, this result was not significant implying that fatigue was not a contributing factor to injury. However, the players had covered 35% more distance at high-intensities than usual before sustaining injury. Previous research in soccer match-play has shown that sprint performance is significantly reduced after the most intense periods of exercise indicating that players experience temporary fatigue [9,28,30]. The present players may have been experiencing some degree of fatigue due to their increased efforts notably at high-intensities thereby affecting their capacity to perform maximally during the injury action.

These findings are supported by a significantly shorter than usual recovery time (~36 seconds versus ~99 seconds in typical performance) observed between the penultimate high-intensity action and the one that led to injury. During multiple sprint work, fatigue is manifested as a progressive decline in functional performance, the magnitude of which is largely determined by the duration of the intervening recovery periods [18]. Therefore, at the time of injury, the present players may have experienced transient fatigue due to incomplete recovery between high-intensity bouts increasing their susceptibility to injury. This reduction could have affected functional performance in areas such as proprioceptive ability [37], dynamic joint stability [25], force production [4], neuromuscular responses [19] or running mechanics [38]. However, caution is required when interpreting these results as to the validity of the method employed for determining a normative profile for each player over a 5-minute period. The work-rate pattern in soccer is random, can vary greatly across match periods and between games and depends on many factors such as scoreline or opposition standard. Nevertheless, researchers should be encouraged on the basis of the present study design and results to explore other means for creating a normative profile for work rate over pre-defined match periods.

These results may have important implications for the design of conditioning regimes to improve player fitness in an attempt to reduce the risk of injury. For example, high-intensity fitness training in soccer traditionally aims to improve the player's ability to recover quickly following successive bouts of high-intensity anaerobic efforts. This effect is achieved through an increased aerobic response, improved lactate removal, and enhanced phosphocreatine regeneration [18]. Specific high-intensity training regimens are traditionally based on work-rest ratios involving the repetition of runs over a set distance and with fixed recovery times [15]. However, the intensity of actions and recovery periods can alternate at any time according to the demands of the match which was the case during the injury incidents reported in this study. Therefore, to optimise player fitness and reduce the chance of injury, practitioners could consider constructing high-intensity training programmes on the repetition of runs that vary in both intensity (duration, distance) and in recovery time.

These preliminary findings may also be pertinent for constructing exercise protocols to simulate the exercise intensities experienced during match-play to investigate the effects of fatigue on injury risk in muscle and joints. Previous experiments have successfully used soccer-specific exercise within the laboratory setting [20,21,31,33,34,39] to monitor changes in performance. However, these protocols tend to measure fatigue after fixed durations (e.g., start, middle and end of exercise) and use a 90-minute exercise period divided into 15-minute normative activity profiles that are identical in terms of intensity. These exercise protocols therefore do not represent the random nature of activity in soccer and on the basis of the present findings, we suggest that future research using such protocols should also investigate impairments in performance after periods of higher than average exercise intensity.

A major limitation of this study was the small number of injury cases examined. In studies of risk factors for sports injuries, a minimum of 20-50 injury cases is recommended [6]. It is inevitable though through comparisons with the low sample sizes obtained in other studies [2,4], that identifying large numbers of real time-loss injuries on video during elite soccer competition is difficult. This limitation of the low sample size is partly countered by the strict injury inclusion criteria combined with the simultaneous access to medical information from team medical staff resulting in a less biased description of how soccer injuries occur [3]. A further limitation was the cohort included players from only one soccer club (as detailed medical information on opposition injuries and physical performance was not available) and the patterns observed may only be a reflection of this particular team. Furthermore, the proportion of injury types (for example, 60% of injuries were sprains) investigated may not fully represent the patterns of injury habitually reported in elite soccer match-play [24,40]. Investigations involving a substantially larger sample of clubs and injury cases are therefore warranted. However, obtaining confidential information and in sufficient quantities on both physical performance and player injury during match-play from elite clubs is difficult. Similarly, no single research approach to identifying the reasons for injury is adequate in terms of completeness of information provided and it is necessary to combine a number of different approaches to describe the mechanisms fully [27]. For example, the impact of extrinsic factors such as the playing situation, game context and opponent behaviour could have affected the present findings. Nevertheless, important practical insights can be gained from studying the events preceding injury and this first investigation is a first step in identifying and understanding the relationship between physical performance and injury in elite soccer competition. It is hoped that similar research on injury data will be done in other professional clubs and associations to build upon the present findings by exploring some of the gaps and questions identified in this report.

Conclusions

The physical demands of contemporary professional soccer match-play are high and players are subjected to fatigue and risk of injury. The present study is the first to have shown that information on physical performance obtained from motion analyses of match-play may be valuable in increasing knowledge about the events involved in the occurrence of injury. These preliminary findings suggest that when there is inadequate time for recovery between high-intensity exercise bouts and the distance and duration of these actions are substantially higher than usual, players may be at increased risk of sustaining injury. Also, analysis of injuries showed that running actions involved both an acceleration phase to achieve high speeds as well as a deceleration phase during which injuries were sustained. Whilst further research is evidently necessary, the findings from this and future studies may eventually be employed in injury prevention strategies by informing the prescription of specific fitness training protocols.

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Table 1 Descriptive characteristics of injuries and movement data for the final running action leading to the injury.

		Injury		Layoff time	Speed (km/h)				Duration	Length	In ball	Contact	Qualitative description of game incident
Position	Type	Location	Time in match		Start	At injury	Maximal	Average	(s)	(m)	Possession		
Defender	Sprain	Ankle	73rd minute	>1 month	0.6	8,0	12.1	9,0	1.6	4,0	No	No	Run then jump to head ball and injured when taking off
Defender	Sprain	Ankle	36th minute	1-4 weeks	12.7	17.5	19.2	18,0	2,0	10,0	No	Yes	Run to intercept ball and injured during challenge for possession
Defender	Sprain	Knee	7th minute	1-4 weeks	8,0	16.4	23.7	18.6	8.8	45.5	No	No	Run to close down opposition player followed by turn and injured during ensuing run
Defender	Sprain	Knee	85th minute	1-4 weeks	5.3	11.7	21.2	18,0	2,0	10,0	No	Yes	Run to intercept ball and injured during landing after challenge for possession
Defender	Sprain	Ankle	7th minute	1-4 weeks	10.9	11,0	11.3	11,0	2.5	11,0	No	Yes	Run to cover space and injured while challenging for possession
Defender	Strain	Groin	32nd minute	1-4 weeks	1.8	16.9	30,0	20.9	11.4	66.4	No	No	Run to meet pass and injured when controlling ball
Centre-forward	Fracture/dislocation	Ankle/Lower leg	25th minute	>1 month	5,0	12.8	22,0	16.1	5.6	25.1	No	Yes	Run to close down opposition player followed by turn and injured during ensuing tackle
Centre-forward	Bruising/Hematoma	Thigh	24th minute	1-4 weeks	5.4	9.4	26.6	21.2	11,0	64.7	No	Yes	Run to meet pass and injured during challenge for possession
Centre-forward	Sprain	Ankle	16th minute	1-4 weeks	9.2	19.3	30.2	16.9	5.1	24,0	No	Yes	Run into space and injured during challenge for possession
Centre-forward	Strain	Hamstring	23rd minute	1-4 weeks	2.9	18.7	22.4	16.2	6.5	29.2	Yes	No	Run into space to collect possession and injured when passing
Mean ± SD					6.2±4.0	14.2±4.2	23.0±6.5	16.6±3.8	5.7±3.7	29.0±22.7			

Mean ± SD

Table 2 Comparison between the players' normative physical performance profile over a typical 5-minute game period and the 5-minute period leading up to the injury; and comparison between the normative physical performance profile for a typical high-intensity action and the high-intensity action during which injury occurred.

	Normative	Injury Action	Mean difference	Effect Size
Distance covered in 5-min period leading to injury (m)				
Total	569.2 ± 28.2	594.5 ± 88.3	25.3 ± 84.8	0.36
High-intensity	44.2 ± 11.2	67.0 ± 57.3	22.8 ± 61.9	0.53
Moderate-intensity	82.0 ± 14.0	84.8 ± 45.5	2.8 ± 47.3	0.06
Low-intensity	81.7 ± 15.2	87,1 ± 31.4	5.4 ± 30.6	0.19
Walking/jogging	361.4 ± 6.0	355.6 ± 59.9	-5.8 ± 59.9	0.08
Characteristics of final high-intensity runs leading to injury (n=8)				
Length (m)	15.7 ± 0.4	27.6 ± 18.7	10.9 ± 18.8	0.71
Duration (s)	2.5 ± 0.1	4.2 ± 2.7	1.7 ± 2.7	0.50
Speed (km/h)	22.2 ± 0.2	22.0 ± 1.7	-0.2 ± 1.8	0.00
Recovery time after previous high-intensity run (s)	98.8 ± 17.5*	35.6 ± 16.8	-63.2 ± 26.6	3.50

* Significantly greater recovery time (p=0.003)

Mean ± SD